The NLX220 Fuzzy Logic Controller

To develop an algorithm with the NLX220 fuzzy logic controller, simply divide your input and output (I/O) into regions and use them to write IF...THEN rule statements, in these three easy steps:

1. Name your I/O
2. Define the Fuzzy Variables
3. Write your Rule Set.

I/O

I/O encompasses the naming of the input and output values. This gives a "tag" to the value that will be used in the design. Use logical names for your input and output values. (E.g., An input for a sensor measuring a motor's rpm may be called SPEED.)

Fuzzy Variables

Fuzzy variables are defined regions of an input or output range. The internal structure of the NLX220 has 8-bit resolution. Thus the possible value of all I/O is 0 to 255. Membership functions (see diagram for examples) divide this range into the fuzzy variable regions and are the vehicle used to translate crisp data into fuzzy data. Each fuzzy variable is composed of a membership function and an I/O. A membership function has three values:

1. center, a locating value within the range (i.e., 0 to 255),
2. width, the region of the membership function that is scaled (i.e., not 0 nor the maximum value of 63),
3. type, an indication of which of the six membership functions is used.

When a fuzzy variable is written, it appears in this format (with example):

{I/O name} is {fuzzy variable name} ({center}, {width}, {type})
SPEED is SLOW (120, 5, symmetrical inclusive)

A special feature of the NLX220 is the floating membership function. The floating membership function allows you to define a fuzzy variable with the center and/or width as another I/O value. For example, if you had a second input labeled OLDSPEED which was a time delayed value of the rpm sensor, you could compare your SPEED value to it in this manner:

SPEED is SLOW (OLDSPEED, 5, right exclusive)

When the system runs, each fuzzy variable is evaluated based upon the I/O's value. The fuzzy variable's value can range from 0 to 63 and is the defined membership's y-axis value at the I/O's x-axis point.

Rule Set

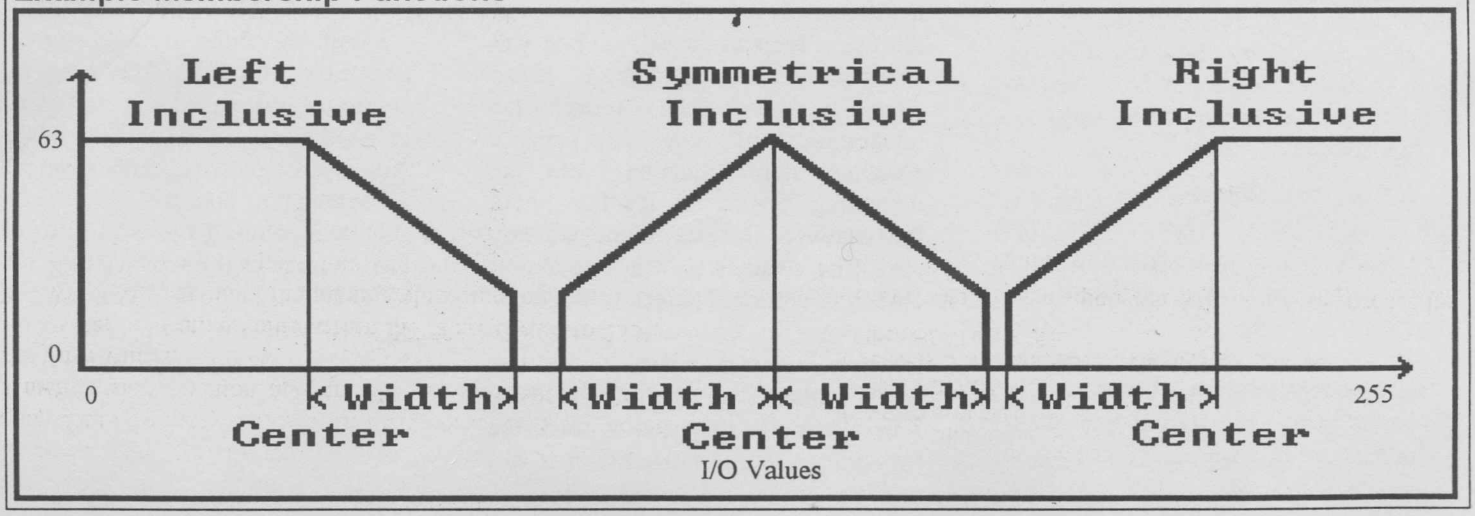
In writing the rule set, use the fuzzy variables in IF...THEN statements to modify the output values. You can use one or more fuzzy variables in each rule but only one output value is affected per rule. You can set the output to an "immediate" value (e.g., 128, 255, or an I/O value) or have an "accumulated" value added to it (e.g., +5, -2, or an I/O value). This is how the rules will appear (with examples):

if {fuzzy variable 1} and {fuzzy variable 2} and {etc.}
  then {output name} =/+ {value}
if SPEED is SLOW
  then POWER +5
if TEMP is COLD and HEATER is OFF
  then HEATER = 255

Rules are evaluated based upon the MAX-of-MIN procedure. The NLX220 assigns the minimum valued fuzzy variable's value within a rule to that rule and then selects the rule with the maximum value as the winner. Only rules relating to the same output are compared to each other in the rule comparison.

If you have questions concerning this or would like assistance with your applications, please call (408) 383-7200. Adaptive Logic is dedicated to helping you complete your design.

Example Membership Functions



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The Basics of PID on the NLX220

Abstract: *Control algorithms in electricity often use differentiation and integration. Adaptive Logic's NLX220 fuzzy logic controller realizes these processes by utilizing its patented floating membership function. Doing differentiation and integration with the NLX220 open the way for engineers to quickly design PID controls in fuzzy logic.*

Electrical control often involves Proportional-Integral-Derivative (PID) control. This process is a standard in industry. Implementation of PID control requires differentiation and integration. In the past doing these functions in fuzzy logic have been hard due to the difficulty in comparing values. This is no longer the case.

With the NLX220 fuzzy logic controller integrals and derivatives can be done quickly and easily by using its floating membership function. Adaptive Logic's patented process allows the user to compare and differentiate input and feedback values. Let us take a look at how the two basic calculus operations of differentiation and integration are done on the NLX220.

DERIVATIVES

Recall that the derivative is the difference in y divided by the difference in x between two points on a line as the change in x goes to zero. In electricity, the x value is almost always time and y is normally either voltage or current. In theory a true derivative occurs at the limit of $x \rightarrow 0$. In digital systems this is not possible and we must deal in discreet time differences. Generally, the sampling speed in the NLX220 for each input is as fast as 10KHz (0.1 msec) depending upon the clock speed used.

There are two ways to find the difference in y (voltage) on the NLX220. One is to feed the input value that is being differentiated through to a feedback output register. This would then be available on the feedback register the next cycle. The other is to use an external time delay circuit (such as a simple RC circuit) to feed the delayed value into a second input. Either way, you have two values and a known change in time for the input you are differentiating. These input values can now be compared by using the NLX220 floating membership function. This is done by defining a group of fuzzy variables for one of the values using the other value as the center point in the membership functions. Such a set may look like this:

TEMP is OK (TDELAY, 2, sym. inclusive)
TEMP is Drop (TDELAY, 2, right exclusive)
TEMP is Rise (TDELAY, 2, left exclusive)

Each Fuzzy Variable is a comparison of TEMP and the delayed TEMP value of TDELAY. As there is no overlap of these fuzzy variables only one will ever be non-zero. Action can then be taken as needed by the application. For more examples of derivatives in the NLX220 see the Smart Heater, Battery Charger, Loop Control, and Fan Demo application notes produced by Adaptive Logic.

INTEGRATION

Integration is helpful in tracking position and reducing overall error. If you graph a voltage input against time, the derivative will tell you the slope of the line. Integration of that line will give you the area underneath it. If you have a steady-state input, the integration over time will yield a constant slope function with an increasing value. If the input fluctuates, the integral's slope will vary too. The steady-state value is almost always the desired effect in controls. In this case it is often more desirable to integrate the error (difference from set point) rather than the actual input. This eliminates the need to track the "integration value" (Actually, this is a summation due to the limits of discreet time.) of the set point. By integrating the error each cycle, the system will be capable of determining whether the process is running behind (less than the set value) or ahead (greater than the set value). Action then can bring the desired value back to the set point.

Integration in the NLX220 requires one of the outputs to be used as an integration register for tracking changes. Fuzzy variables are defined for the input based upon its quantitative value. Example of such fuzzy variables would be:

SPEED is SLOW (120, 5, sym. inclusive)
SPEED is OK (130, 5, sym. inclusive)
SPEED is FAST (140, 5, sym. inclusive)

Depended upon which fuzzy variable is the winner, a value is added to the integration register. (For example, if SPEED is SLOW add -1, if SPEED is OK add 0, and if SPEED is FAST add +1.) The integration register will need to be set to a mid-range value at the start up (e.g., 125) so as to allow for negative changes in integration. One can then take action depended upon the difference in the integration register from its initial value.

With the ability to do integrals and derivatives on the NLX220 fuzzy logic controller, the engineer is now capable of implementing PID in Fuzzy Logic. Adaptive Logic is currently developing an application note for approximating PID control using the NLX220. You can request a copy by calling (408) 383-7200. It will help you learn how to intelligently use fuzzy logic with the NLX22X family of fuzzy logic controllers.

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